

## Community And Farm Forestry Climate Mitigation Projects:

### Case Studies From Uttarakhand, India

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**Abstract.** The methodologies for forest mitigation projects still present challenges to project developers for fulfillment of criteria within the Clean Development Mechanism or other such mechanisms for the purpose of earning carbon credits. This paper systematically approaches the process of establishing carbon stocks for baseline and mitigation scenario for two case studies ie. *community* and *farm forestry* projects in Uttarakhand, India. The analysis of various interventions shows that both projects present high carbon mitigation potential. However, the carbon reversibility risk is lower in long rotation pine and mixed species plantation on community lands. The project is financially viable though not highly lucrative but the carbon mitigation potential in this ‘restoration of degraded lands’ type of project is immense provided challenges in the initial phase are adequately overcome. Carbon revenue is an essential driver for investors in community projects. The short rotation timber species such as Eucalyptus, Poplar have high internal rates of return (IRR) and high carbon benefit reversibility potential due to fluctuations in market prices of commodities produced. The land holdings are small and bundling is desired for projects to achieve economies of scale. The methodological concerns such as sampling intensities, monitoring methodologies, sharing of benefits with communities and bundling arrangements for projects need further research to make these projects viable.

**Keywords.** mitigation, carbon, farm forestry, community forestry, financial feasibility, baseline, additionality.

## 1. Introduction

Tree growth serves as an important means to capture and store atmospheric carbon dioxide in vegetation, soils and biomass products (Makundi and Sathaye, 2004). Expanding the size of the global terrestrial sink is one strategy for mitigation of atmospheric carbon dioxide build up. Currently, the total aboveground biomass in the world’s forests at  $421 \times 10^6$  tonnes is distributed

over a total area of 3869 Mha; 95% of this is in natural forest and 5% in plantation forest (FAO, 2001). Carbon in forests constitutes 54% of the 2,200 Gt of the total carbon pool in terrestrial ecosystems (FAO, 2001). Newly planted or regenerating forests, in the absence of major disturbances, are likely to continue to uptake carbon for 20 to 50 yrs or more after establishment, depending on species, site conditions and the objectives of plantations. A recent assessment of land use, land use change and forestry (LULUCF) mitigation options suggests that the global potential for biologically feasible afforestation and reforestation activities between 1995 and 2050 could average 1.1 -1.6 Gt C yr<sup>-1</sup>, of which 70 % would be in the tropics (IPCC, 2000).

Total aboveground and belowground biomass in India's forests is estimated at 6,865.1 and 1,818.7 Mt C respectively (Ravindranath et al., 1997). The mean biomass density is 135.6 t ha<sup>-1</sup> (Chhabra *et al.*, 2002). India's first national communication to the UNFCCC reported the LULUCF sector contributed only 2% of the total GHG emissions from all sectors, for the reference year 1994 (NATCOM Report, India 2004). It estimates a net uptake of 14,252 Gg of CO<sub>2</sub> due to changes in forest and other woody biomass stock that includes carbon release due to extraction of timber and traditional wood use. There are no net emissions from India's forests because natural regeneration and plantation biomass growth sequestered carbon equivalent to the estimated emissions for the forest sector (Ravindranath et al., 1997).

One study of India estimated an annual mitigation potential in the range of 23 to 175 x 10<sup>6</sup> Mg C, requiring an annual investment of US \$ 2.1 billion in 1994 dollars over a six-year period (Ravindranath and Somashekhar, 1995). Another study has shown that a sustainable forestry scenario could lead to an additional carbon stock of 237 x 10<sup>6</sup> M g C during 2000 – 2012, while a commercial forestry scenario could potentially lead to an additional carbon stock of 78 x 10<sup>6</sup> M g C during 2000 – 2012, in addition to meeting all incremental biomass demands (Pandey, 2002).

Therefore significant forestry mitigation potential exists in tropical countries such as India, which has around 20% of geographical area under generally understocked forests, substantial degraded land available for afforestation, and potential for tree planting outside of forests on farms. This potential, however, may vary depending upon the suitability and availability of land for afforestation and reforestation, competition for land and capital with other options for mitigation,

and the country's and international demand for GHG mitigation. Additionally, forestry projects on degraded soils can lead to significant C sequestration in soil organic matter build up (Lal, 1999). Agroforestry as a mitigation strategy holds promise because of the ancillary co-benefits that help to attain food security and secure land tenure in developing countries, including provision of fodder, biofuels, wood and revenues (Pandey 2002).

The contentious issues in forestry mitigation projects have been those of the risk of loss, uncertainty, and permanency of the carbon credits generated from this source and therefore the mitigation value offered by this vast terrestrial resource. For project developers interested in this sector, however, there are difficulties associated with the assessment of the existing carbon, the potential carbon, the expected returns, the vagaries of land use pattern and the leakage estimations.

This report presents two case studies (not being implemented) from Uttaranchal to assess carbon stocks under baseline and mitigation scenarios on a project scale (up to 5,000 ha). The tasks undertaken include:

- Identification of potential areas in the project site for two types of afforestation (Community Forestry on *Van Panchayat* lands (community lands) in Betalghat, and Farm Forestry on private croplands in Bazpur.)
- Establishing baseline and mitigation scenario carbon estimates
- Assessment of carbon mitigation and financial values using the PROCOMAP spreadsheet model
- Leakage estimation for project viability
- Analysis of other barriers to implementation of the mitigation project.

#### **About the State of Uttaranchal**

The state of Uttaranchal can be divided into the plain and the hill districts. The scope of forestry mitigation in the plain districts is essentially on the farmlands under private ownership whilst in the hill districts it is through community forestry projects on the community lands locally known as *Van Panchayat lands*.

The Uttar Pradesh Hills popularly known as *Uttaranchal* or *Uttarakhand* are located between latitudes 29°5' -31°25'N and longitudes 77°45' - 81°E covering a geographical area of

53,485 km<sup>2</sup>. Uttarakhand is predominantly a mountainous state, situated in the Central Zone of the Himalayas between the state of Himachal Pradesh to the west and the country of Nepal to the east. The total area is 53,119 sq. km., which accounts for about 1.6 percent of the total area of the country.

### **Land Use and economic activities**

Forest is the most significant land use in Uttarakhand. Almost 64% of the total geographical area of Uttarakhand is under forest cover, about 6% is cultivable waste land, 4% tree crops, 4% permanent pasture and grazing, 1% fallows, and 12% sown with crops (according to Plan Documents, Uttarakhand Vikas Vibhag, Government of Uttar Pradesh). On this account, in terms of relative ranking Uttarakhand is the fourth most forested state in India.

The entire State demonstrates a wide range of intra-regional variation of topography (rugged and mountainous terrain), soils, and climate, and supports small villages and an agriculture-based economy. Uttarakhand can be divided into the plain districts generally in the southern Terai zone, comprised of farmlands under private ownership, and the hill districts to the north, supporting community forestry on commonly held *Van Panchayat* lands.

## **2. Case Study 1**

### **Carbon Mitigation Potential Through Community Forestry In Betalghat Watershed**

#### **2.1 Description Of Study Area**

The study area is comprised of namely- the Ramgad and Kosi micro-watersheds in the Betalghat block of Nainital district, adjoining the boundary of the Almora district. The river Kosi flows through the project site with hills rising up to 1,500 to 1,800 m on either side

Rainfall is 1,000 mm, almost 80% of which is received in the July-September monsoon. The main occupation in the region is cattle-rearing and subsistence agriculture of wheat and rice, using contour farming. The productivity of the land is higher along riverbeds and drops on steeper slopes subject to soil erosion. The farmers also plant fruit trees such as mango, citrus fruits, pears and plums on the private fields.

Two major land categories are present in the project areas:

1. **Betalghat Community Forestry:** Vast areas are under the management of the local communities. These *Van Panchayat* lands are a proportion of Civil Soyam or Revenue forests which have been consolidated and transferred to the local communities for management, though ownership still remains with the Revenue Department. Human pressures have degraded formerly dense forests to current vegetation cover of less than 10%, now used for grazing cattle and are known as *Gauchars*, and for biofuels. The *Van Panchayat* lands generally have a low-carbon baseline, and hence represent areas with large carbon form of small size landholdings of less than 1 ha.mitigation potential (Table 1). Private lands are minimal and those that do are in the
2. **Bazpur Farm Forestry:** This mitigation option is on agricultural lands under private ownership of farmers (Table 1). The farm forestry option is limited in scope in Betalghat as agriculture area is hills is limited in extent compared to flat plains in Bazpur. Minimal *Van Panchayat* lands exist here.

TABLE 1

Overview of the study sites and carbon mitigation options.

**PLACE TABLE 1 HERE**

#### *Distribution of Van Panchayats in Uttaranchal*

There are more than 7,000 *Van Panchayats* in the state that manage nearly 11.7% of the revenue forests. (Fig. 1).

**FIGURE 1 HERE**

*Figure 1. Distribution of Van Panchayat institutions managing Van Panchayat lands in Uttaranchal State (Adapted from Kumar A., 2000)*

#### 2.2. Methodological Approach Procomap

The analysis used the Project based Comprehensive Mitigation Analysis Program (PROCOMAP) built on the COMAP model structure (Sathaye et al., 1995), a Microsoft Excel-based

model with the ability to analyze the mitigation potential as well as cost-effectiveness of mitigation activities such as Natural Regeneration (with no logging), and Afforestation/Reforestation through plantation forestry, including short- and long-rotation forestry (with logging and harvesting allowed). The methodological approach is summarized in the flow diagram Fig. 2 (from Sathaye et al. 1995).

**PLACE FIGURE 2 HERE**

*Figure 2.* Flow diagram of approach to mitigation analysis using PROCOMAP model.

The PROCOMAP runs the analysis in two parts: the Baseline Scenario of carbon emissions mitigation under the ‘business as usual scenario’ where no deliberate effort is made to reduce carbon emission, and the Project Scenario where mitigation options are designed for land use and the carbon mitigation potential is calculated over a defined time period.

### 2.3 Methodology For Assessment Of Carbon Mitigation Potential: Scenario Development

#### *Selection of Project Area*

The land use mosaic is presented in Fig. 3. This complex, fragmented, small-parcel land tenure situation limits mitigation options to the ones assessed.

**PLACE FIGURE 3 HERE**

*Figure 3.* Schematic map of land use and mitigation options in hilly areas of Betalghat watershed.

The reserve forest areas (170 ha) are not included for plantation purposes but are within the geographical boundary of the project area. The forest areas are not directly under community control and are therefore excluded as potential areas for afforestation. The total project area is 4,881 ha and the effective plantation area is 1,589 ha (Table 2). The area where constitution of Van Panchayats have been completed totals 2,075 ha. Civil/Soyam lands represents remaining revenue areas likely to be transferred to Van Panchayat status in the near future. The number of villages in the project area is 48 with 2,767 residing families and a total population of 19,945 (Panchayati vanon ke sanhad prabhand yojana, janpad Nainital; Varsh 2003-08).

TABLE 2

Area by land use category in the Betalghat project site.

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Data from forest records were used to establish the baseline rates of afforestation and plantations in the project site. There was wide variability in the past rates of afforestation as well as tree survival percentages observed in the field. The sampled villages showed that on an average the rate of afforestation between 1996 and 2000 varied between 8 ha per year to 15 ha per year at the village level. In some villages no plantations have been established in the last 5 years.

The survey showed that only selected areas were taken up for plantation activities in the project area under different centrally and state-sponsored programs. The management plan for Nainital Forest Division has identified potential areas for afforestation in Betalghat block. However, due to financial and other constraints, the envisaged targets remain underachieved. Based on a survey, secondary data and information from forest records, the estimated rates of plantation per annum in the project are between 30 ha to 214 ha. The average annual plantation rate for the last 5 years is 133 ha, with a sharp declining trend in plantation rates in the last 2 years. If this trend continues, the carbon stocks for the baseline scenario would be expected to decline over time due to the declining afforestation rates. Field measurements for onsite carbon stocks for the reference year 2003-2004 should sufficiently reflect the average carbon stock for the reference case. As a conservative approach the baseline carbon stock beyond 2005 is assumed to remain static rather than decline further assuming that afforestation rates would not drop beyond the 30 ha per annum figures in future.

Field work estimates show vast stretches of area available with no tree cover on hill slopes on either side of River Kosi. Out of a total of the nearly 4,881 ha identified in the project site, the areas technically fit and available for afforestation comprise 1,759 ha (Table 3). North-facing and steep slopes not fit for plantation other than protection forests have been excluded. Species planted in departmental and private plantations include Chir pine, Silver oak, Bauhinia and Surai; and fruit tree species such as Mango, Citrus and Aonla. Most of the *Van Panchayat* lands are barren areas with poor growth. However, the villages adopted under the Integrated Watershed Development Programme by the State Government have shown promising results in terms of improved vegetative

cover and meeting fuel and fodder requirements of the people, thus indicating the feasibility of restoration.

### ***Ground Survey and Data collection***

Five villages were selected via stratified random sampling based on village size and per capita land area. The socioeconomic profile of the villages shows that per capita land area distribution (Civil, Van Panchayat, and Agriculture) varies between 0.01 ha to 1.0 ha. The majority of the land ownership is in the category of 0.3 to 0.5 ha, and in only 2 villages the per capita land area is 0.7 to 1.0 ha. Quantitative data was collected using structured questionnaires (with semi open, closed and ranking questions) and qualitative data using semi structured interviews to collect information. Information on land use, tree plantation activities, plantation trends, area availability for future plantations, socioeconomic parameters, and dependence on forest area and farmlands for fuelwood, fodder and small timber was recorded. Participatory rural appraisal techniques and group discussions with the community and forest department staff were used to assess the choice of species, the area that could be spared for afforestation and reforestation (A and R), the fuelwood and fodder demands, and the locations from where these needs are met. Technical information pertaining to the growth and yield of species, rotation age, market prices etc. was obtained from forest corporation, forest department records, published reports and surveys where appropriate (such as fruit tree species).

### ***Description of Baseline Scenario***

A baseline scenario (BSL) in the forestry sector is described to serve as a current reference point, for comparison with future scenarios (including the incorporation of a mitigation strategy). The base year for this study is 2003-2004. The basic premise for developing such a scenario is to develop, in the absence of any climate considerations, GHG flows, costs and benefits, minus the proposed project interventions. Ground surveys and current rates of afforestation from Area Management Plans constitute the basis for this scenario. We assume that the current rates of afforestation would continue at the level of funding available and that carbon would be sequestered at these rates without major interventions.

The steps in establishing the baseline scenario are:



- Identifying all the land use systems and demarcation of areas under each category
- Identifying the project boundaries and preparation of maps
- Assessing of existing carbon stock in aboveground, belowground and soil carbon in each category through field sampling

Estimating the rate of change of carbon stocks in absence of any intervention with respect to the base year.

### ***Description of Project Scenario***

The Mitigation Scenario (MSL) is developed with respect to the proposed mitigation interventions. This scenario estimates GHG flows and benefits, and the incremental costs for the intervention above the BSL. Financial analysis for each intervention in the project scenario determines the feasibility of the proposed activity.

## **2.4 Carbon Stock Estimation**

### **Carbon stocks**

Baseline carbon was estimated for each of the potential land use classes identified in the project site (Table 3). Five sample villages were selected and for each intervention designed, estimation of biomass and soil carbon under baseline and mitigation scenarios was estimated so that mitigation potential could be calculated under different project interventions. Five representative sample plots (0.1 ha quadrats) were selected and all trees above 10 cm diameter breast height (dbh) were measured for diameter and height. Aboveground biomass was worked out by using relevant biomass equations/factors and belowground biomass was calculated as a percentage of the AGB ( $BGB = ABG * 0.26$ ). Carbon was calculated by multiplying the dry biomass value by 0.45. Growth parameters such as tree height, diameter were measured in sample plots. Samples of wood, litter and soil were collected and field surveys conducted to estimate the carbon sequestration through major interventions. Community choice of species and the land suitability was a major factor in deciding the species to be used for afforestation. Species were selected for the project scenario based on Rapid Rural Appraisal and Participatory Rural Appraisal exercise.

For estimation of soil organic carbon, three representative soil samples were drawn to 30 cm from within each quadrat, and analyzed for soil organic carbon using the Walkley and Black

method. For estimation of woody litter all fresh twigs, branches and other woody parts of the trees fallen within a year were collected from a unit area ( $\text{m}^2$ ) from three randomly selected sites within the quadrats following Pande and Sharma (1993). The values for biomass and soil carbon obtained were within the range reported for an age series of Chir Pine forests and temperate forests of Himalayas intensively studied by Singh and Singh (1992).

The PROCOMAP model was used to estimate carbon stocks in baseline and mitigation scenarios. It takes into account five C-pools, i.e., aboveground biomass (AGB), belowground biomass (BGB), woody litter, soil carbon and harvested wood products.

TABLE 3

Carbon ( $\text{t ha}^{-1}$ ) in aboveground, belowground and soil carbon pools under different land uses in project area.

**PLACE TABLE 3 HERE**

The carbon content differences are essentially the result of different land use practices. The agricultural areas have higher organic carbon due to better soil management, terrace farming and manuring, while the Civil/Soyam soils have been subjected to grazing, so gradual deterioration in soil carbon is evident.

## 2.5 “Additionality” On Land Use Types Proposed In The Project Scenario

*Additionality* of GHG benefits beyond the base case needs to be demonstrated for some mitigation programs. For example, the Clean Development Mechanism guidelines under the UNFCCC defines additionality as: *An afforestation or reforestation project activity is additional if the actual net greenhouse gas removals by sinks are increased above the sum of the changes in carbon stocks in the carbon pools within the project boundary that would have occurred in the absence of the afforestation or reforestation project activity.*

By the above definition, *additionality* is not an issue in Betalghat as records are available to show the poor vegetative cover status of the lands for the last 20-30 years, or even earlier and declining trends in plantation establishment rates. The *additionality* tool developed by the A and R working group of the CDM (UNFCCC) was applied as an analytic exercise to determine project

*additionality* by financial and legal criteria. The following stepwise approach can be adopted to show *additionality* in *Van Panchayat* lands.

- Identification of alternatives to A and R project activity (Project Scenario) consistent with current laws and regulation.
  - The *Van Panchayat* and *Civil Soyam* lands are characterized by low existing rates of carbon sequestration, and degradation due to human interference and lack of management. The most likely land use at the project start time is continuation of the current situation, as financial resources available within the communities do not allow improved management for increased carbon sequestration. The existing *Van Panchayat* rules provide for management of these lands by the *Van Panchayat* institution for meeting the fuelwood, timber and fodder needs of the communities. The enforcement of rules in the past has been weak and common practice is to allow grazing and fuelwood collection in the areas without consideration to alternative interventions to improve land productivity.
  - A second alternative baseline scenario could be that areas were afforested or reforested at the past rates of conversion to plantation as projected in Table 4 with assistance from forest departments. The total area afforested in the project area is 665 ha in the last 5 years with the scope to increase afforestation and reforestation by another 1789 ha in the project scenario at an average of 160 ha/annum, considering a 10-year phasing in of proposed interventions.
- Investment analysis to determine that the proposed project activity is not the most economically or financially attractive.
  - Investment analysis has been performed as a stand-alone *additionality* analysis only for proposed interventions. Capital costs, maintenance costs and opportunity costs have been included and financial *additionality* of the project is demonstrated. The analysis concludes that the proposed A and R project activity is unlikely to produce economic benefits without financial benefits from carbon revenue and is therefore additional (See ‘financial analysis’ section of report).

- Barrier analysis: The barriers that would prevent the implementation of the proposed project activity have been identified and discussed in later sections and show project *additionality*.

Thus the project scenario meets at least this one set of *additionality* criteria in more than one way.

## 2.6 Financial Analysis

The PROCOMAP analysis modules also estimate the internal rate of return (IRR) for long rotation, short rotation, and natural regeneration scenarios with and without carbon revenue. The IRR with carbon revenue was estimated for three scenarios C1, C2 and C3. C1 scenario assumes a consistent carbon price of \$5 per tC (Rs. 230; Exchange rate 1\$=Rs.45) with no increase with time, C2 scenario where carbon increases at the rate of 2% per annum and C3 where carbon price increase is at the rate of 5% per annum. The maximum carbon price attainable in scenarios C2 and C3 is \$ 100 (Rs.4,600). This analysis shows the project *additionality* with respect to carbon returns. The carbon price per ton at the hurdle rate, i.e., where the barriers will be overcome, was also estimated.

The costs include the opportunity cost of the land, the silvicultural, harvesting, monitoring costs of biomass, soil carbon and other maintenance and protection costs associated with the afforestation activities. The costs in slow-growing, long rotation plantations extend up to 6<sup>th</sup> year due to weeding and protection costs. The opportunity costs are estimated on the basis of current land use, ownership status and potential use of land in foreseeable future. The benefit analysis is based on prevailing market rates of chip logs, fruits, resin and fuelwood, which are the main products in the mitigation interventions besides carbon. Resin used to be in high demand in the region as this belt is a naturally occurring chir pine zone. The prices of resin are not very lucrative at present at Rs.25,000 per ton and hence only 30% of the project area has been assigned for this species though the growth potential of Chir pine on *Van Panchayat* lands is higher.

The afforestation and reforestation mitigation projects require funds for protection silvicultural, maintenance practices for subsequent care of the plantations and monitoring. The cost of the project is therefore more than the initial cost of establishment calculated for the first three years. The other costs include expenditure associated with thinning, fuelwood extraction, fruit

collection and marketing and resin tapping. The sum of investment and annual costs for the life of the project is converted to present value using a discount rate.

## 2.7. Results

### ***Carbon stock Analysis- Mitigation Scenario***

Almost 50% of the Civil and Van Panchayat and 25% of the total agricultural land in project area were potentially available for afforestation and reforestation in survey conducted, for the following species choices (Table 4).

- a. Plantations on Van Panchayat and Civil Soyam lands – Chir Pine, and mix of *Alnus* sp., *Cupressus* sp., and *Fraxinus* sp., for fuelwood and fodder requirements and non-timber products mainly resin. These are degraded lands on mid to high altitude sites.
- b. Plantations on Van Panchayat and Civil/Soyam lands - Riparian planting of Khair (*Acacia Catechu*) mainly along stream/river banks. These are relatively flat areas along river beds and relatively more fertile than degraded lands described in a. above.
- c. Fruit species on Agriculture lands - fruit species such as Mango and Kinoo.

TABLE 4

PROCOMAP Key Input Data.

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The PROCOMAP model was run without accounting for wood products except for Khair in the project period (2000-2035) and pine at 80 yrs (2085).

Assuming conservative estimates, the baseline carbon has been projected as static for all interventions where no changes in anthropogenic or natural activity are expected over the project period (Richards and Anderson, 2001), as is the case in Van Panchayat lands. Under the mitigation scenario the major changes in C stock accrue due to changes in aboveground biomass carbon stock following afforestation and reforestation. The incremental C stock for various interventions in the year 2035 in increasing order is Kinoo 4.1, Khair 23.2, Mango 55.3, Mixed 197.9 and Chir Pine 250 tC/ha (Table 5)..

TABLE 5

Carbon stock change under baseline and mitigation scenario and the carbon increment per ha for various interventions for the period 2005-2035 (tC/ha).

**PLACE TABLE 5 HERE**

The wood products pool is significant only after 2085 when pine plantation is harvested at 80 yrs rotation and sawlogs are the major wood products. In the 30-year analysis, the wood products returns are not reflected. Aggregate annual carbon stock increment in aboveground, belowground, soil, litter and wood products C pool is shown in Fig. 4. Except for Kinoo and Khair the rotation age for other interventions is 60 years or more and for this reason there is net carbon accumulation in all pools up to the 80<sup>th</sup> year. The soil carbon stabilizes in 2045, approximately at the 40<sup>th</sup> year.

**PLACE FIGURE 4 HERE**

*Figure 4.* Aggregate annual C stock increment in different C pools for all project activities in Betalghat.

The aggregate carbon stocks under baseline and mitigation scenario are shown in Fig. 5. At 30 years the net mitigation is 197,242 tons of carbon which increases to 479,905 tons without wood products at 80 years. Beyond 80 years this potential is further increased due to carbon benefits from wood products.

**PLACE FIGURE 5 HERE**

*Figure 5.* Aggregate carbon stocks under baseline and mitigation scenario for project activities in the Betalghat.

The aggregate carbon flow under the mitigation interventions over 30 years for the entire project area of 1,589 ha is 197,242 tC ( $\Delta C$  pool under mitigation-  $\Delta C$  pool under baseline) with average annual incremental rate of 4.1 tC per ha if all plantations are successfully established and maintained. (Table 6).

TABLE 6

Average annual incremental carbon and total carbon sequestered under tree plantation (without wood products) for assessment period (2005 – 2035).

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The carbon pool is estimated for chir pine and mixed plantations with a no harvesting regime. The carbon stock under fruit species and khair is relatively low essentially due to the small proportion of total area dedicated to these plantations and the slower biomass increment.

In interventions such as pine or mixed species afforestation, where returns are delayed, investors may be unwilling to invest except for incentives due to carbon in the early years of project implementation. The projects would be suitable as carbon mitigation projects with allowance of adequate flow of early returns from sale of carbon.

### ***Financial Analysis***

The benefit cost analysis and the internal rate of returns were calculated for each of the mitigation interventions using the PROCOMAP model. The opportunity cost for *Van Panchayat* lands is Rs. 2,000 and is low compared to Rs. 8,000 for croplands, since VP lands are degraded and a common property resource (Table 4). The establishment costs per hectare range between Rs.10,000 to Rs.18,938 (\$222 to \$389). Unit cost of carbon sequestration ranges between \$4.7 for mixed plantation to \$458 per ton of carbon for kinoo fruit. The unit cost of carbon for all interventions except kinoo is less than \$100 per ton (Table 7). The weighted average cost per ton of carbon for the project area is Rs 3,988 (\$88.6) per t carbon. The costs of mitigating pressure from grazing and providing alternate sources of protection for the young plantations need to be included and will further raise the per ton cost of carbon sequestration.

The per hectare mitigation potential on weighted average basis with the proposed interventions is 113 tC per ha over the 30-year period. Maximum per ha potential is under Chir pine with 213 tC ha<sup>-1</sup> followed by mixed plantation species 163 tC ha<sup>-1</sup> (Table 7).

TABLE 7

Establishment cost and carbon stored under tree plantations.

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The cost effectiveness indicators were worked out at three discount rates and the NPV reflects the benefit /loss to be obtained from implementing the project activities without carbon revenue (Table 8). For the project period 2005-2035, the NPV is positive for Kinoo, Mango and Khair interventions upto 8% discount rate. The project interventions could be considered viable if

the investment funds are obtained at discount rates of up to 8% for Khair, Kinoo and Mango as IRR for Khair is 8.5%. The higher IRR's for fruit species show that these products are in high demand locally compared to other products.

For pine and mixed specie plantation the IRR is 2.2% and negative respectively until the year 2035. The IRR increases to 8.5% for pine at rotation age (2085) when benefits from resin and wood products are also included from age 40 years onwards. For mixed species plantations the IRR is only 3.5% without carbon benefits from wood products or carbon. The internal rate of return is an indicator of the threshold interest rate below which the investment fundings can be obtained to keep the project financially viable. In the short term therefore, the long rotation interventions without carbon revenue are not feasible.

TABLE 8

Cost effectiveness indicators for mitigation options for the period 2005-2035.

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The feasibility of interventions when revenue from sale of carbon was included as per scenarios C1, C2 and C3 described in section 1.3.1 gave the IRRs presented in Table 9.

TABLE 9

Internal rate of return for project interventions with carbon revenue.

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The details are described for Khair, Pine and Mixed plantations in the following paragraphs.

**Khair:** In case of Khair, IRR is 8.5% without revenue from sale of carbon. This IRR is less than the prevailing bank interest rates. Hence, this intervention is not viable without carbon revenue and thus meets the condition for additionality. Including the carbon revenue at Rs. 5 per tonne C, the IRR increases to 9%, 10.7% and 13.1% for the scenarios C1, C2 and C3 respectively (Table 11). Scenario C1 does not adequately meet the benchmark lending interest rate of 10%, Scenario C2 and C3 are viable but the IRR is not very elastic meaning that it increases very slowly with the increase in carbon price at the rate of 5%. This indicates that the share of carbon credits in the total is small, in case no increase in carbon price is assumed then at hurdle rate of 10% the required carbon price is



Rs. 706. The 10% hurdle rate is based on prevailing bank lending rates and is appropriate for long term investments.

**Pine:** In case of pine plantation over the project period of 30yrs IRR is 2.2%. As in Khair, the project is not viable without carbon revenue and therefore meets the additionality condition. The IRR increases to 8.4%, 25.8% and 39.3% in Scenario C1, C2 and C3 respectively. Inclusion of carbon revenue makes this intervention viable for Scenario C2 and C3. Compared to Khair, in pine the rapid increase of IRR's in Scenario C2 and C3 indicate that revenue from carbon is quite substantial. The minimum carbon price required at a hurdle rate of 10% will be Rs. 288 per tonne carbon, or less than half the price of Khair.

**Mixed Plantation:** In mixed plantations, the IRR is negative, which indicates that even at 0% discount rate, the costs are more than the revenue and therefore the project is not viable without carbon incentive. By including carbon revenue in the investment analysis the IRR increases to 3.7%, 17% and 24.6% in Scenarios C1, C2 and C3. The increase in IRR in C2 and C3 is substantial and makes this intervention lucrative. The returns from mixed plantations are intermediate between those from Khair and Pine. The price of carbon at 10% hurdle rate is Rs. 577 per tonne carbon, which is almost double the per tonne price in Pine plantation. However, it is 0.8 times of required price of carbon in Khair plantation.

Therefore, based on IRR criteria from the sensitivity analysis including carbon, the ranking of plantations is Pine, Mixed plantation and Khair respectively. Without carbon revenue, the ranking is in the order Khair, Pine and Mixed plantation.

**Mango and Kinoo:** The fruit species such as mango and kinoo give IRR of 16% and 20.5% respectively without carbon benefits. These interventions are viable without carbon revenue and hence may not be strictly additional in this context but certain other technical and institutional barriers to implementation do exist that make these options additional.

## **Leakage analysis**

Leakage is defined by UNFCCC documents as *the “net change in anthropogenic emissions by sources of GHG’s and removal by sinks, which occurs outside the project boundary, and which is measurable and attributable to the project activity”*.

The major sources of leakage in the project area are fuelwood and fodder collection. Pressure on vegetation is high due to the higher number of cattle head such as 3,640 bulls, 2,433 cows, 2,478 buffaloes and 2,577 goats. The gaps between fodder and fuelwood supply and demand in the project area are represented in Tables 10 and 11 respectively. An afforestation project can result in leakage for meeting fuelwood needs if the areas of current fuelwood and fodder supply are brought under plantation activities. The leakage estimation was based on an assessment of fodder and fuelwood demands based on household surveys (Table 10 and 11).

TABLE 10

Annual demand and supply of fodder (mt).

**PLACE TABLE 10 HERE**

TABLE 11

Annual demand and supply of fuelwood (tm).

**PLACE TABLE 11 HERE**

An afforestation project can result in leakage for meeting fuelwood needs if the areas of current fuelwood and fodder supply are brought under plantation activities. The leakage estimation was based on an assessment of fodder and fuelwood needs based on household surveys.

Fodder demand is met mainly from forest areas (30 to 35%) and the remaining from cultivated land (20%) and community land (5%) respectively, crop byproducts and private grasslands constitute remaining. Thus only 5% of fodder supply comes from the community lands that are proposed in the project area, i.e., 125 mt annually or 3,750 tons over the project period will come from an area of 1000 ha of *Civil/soyam* and *Van Panchayat* lands. This amounts to 0.125 mt/ha or 125 kg/ha annually. Leakage due to fodder removal is thus 2.1 % of the carbon flow. Similarly the fuelwood requirement is met essentially from the forest areas (60% to 70%) and the Participatory Rural Appraisal (PRA) exercise showed that fuelwood collection from degraded common lands in villages ranged between 5 to 15%. On average we may assume that 7% of annual

fuelwood collection is met from community lands and amounts to 1305 mt from an area of 3,200 ha (total area in community lands in Table 3). The equivalent collection from the community areas of 1000 ha identified in this project is 407.8 mt per annum. Over 30 years (2005-2035) the leakage would be 12,234 mt of biomass.

Hence the fuelwood extraction from wastelands is 0.407 mt or 407 kg/ha/yr. This amounts to 6.8% of total mitigation potential for the site on account of fuelwood leakage alone. Total leakage will not exceed 10% of the project carbon mitigation potential. By the fifth year of project the fuelwood demands should be met from the newly afforested areas. This leakage has not been considered in the financial analysis.

### ***Options to mitigate leakage***

The leakage in *Van Panchayat* lands is under 10% due to low commodity production, whereas on farmlands (see below) leakage is twice that or around 20%, due to production of marketable commodities. Mitigation projects on private lands therefore raise the need to address leakage. One alternative to be considered is creation of buffers that hold 5 to 10% of carbon stock as security for leakage. The interventions in this project were intentionally designed so that no further displacement of fuelwood and fodder collection to adjoining areas would result from the project. As documented in the Harda case study, leakage can be addressed by including fuelwood species in afforestation planning (Poeffenberger et al., 2001). Alternately leakage can be addressed by providing improved chulhas (cookstoves), improved breeds of cattle, and stall-fed cattle to reduce fodder collection.

## **3. Case Study 2**

### **Carbon Mitigation Potential Of Farm Lands Of Bazpur, Udham Singh Nagar**

#### **3.1 Introduction**

Makundi and Sathaye (2004) highlighted the importance of agroforestry as a mitigation option for seven developing countries, where it contributed between 6% and 21% of the mitigation potential and was found to be much more cost effective than A and R.

Fuelwood is by far the most important product extracted from India's forests and accounts for more than 80% of the demand. To meet this demand of industrial wood and fuelwood, large-

scale plantations of fast growing species have been raised along with agricultural crops in northern states of the country, i.e., Haryana, Punjab, Uttaranchal and Uttar Pradesh. Poplar and Eucalyptus are the main species widely accepted by farmers because of low interference with agricultural crops due to their crown structure and favorable silvicultural characters. Large and small farmers have planted them in blocks, lines and bunds (raised field edges) along with crops such as wheat, paddy and sugarcane.

### 3.2 Study area

The study area is spread over 6,200 ha in 35 villages is located in Bazpur block of UdhamSingh Nagar district in southern Uttaranchal state. The area is representative of farmlands of Uttaranchal with almost 80% area dedicated to agriculture. There are good facilities for irrigation and land productivity is high.

The forest area within the selected site is dedicated to production forestry with plantings species of *Tectona grandis*, *Eucalyptus hybrid*, and *Dalbergia sissoo*. *Taungya* cultivation is practiced, wherein the harvested forest area is leased out for agricultural activities to local farmers for a period of three years to grow wheat, paddy, maize, sugarcane, mustard and pulses. The tree species commonly grown with agricultural crops on farmlands are Poplar and Eucalyptus. However, the farmers are slowly switching over to horticulture crops such as Litchi, Mango and some citrus varieties.

### 3.3 Methodology for assessment of carbon mitigation potential

The same methodology as described in case study 1 was followed for developing a baseline scenario, mitigation scenario, and data collection from the field. Five villages (i.e., Majra, Chanakpur, Bhainsai, Vikrampur and Intwa) were selected via stratified sampling based on village size. Structured questionnaires were used for recording of information on land use, tree plantation activities, plantation trends, area availability for futures plantations, socio-economic parameters and dependence on forest area and farmlands for fuelwood, fodder and small timber.

### 3.4 Results

The data on socio-economic profile collected from the selected villages showed that on an average there were 175 households per village with an average population of around 1,000. The

area available for agriculture is 91 ha per village and the majority of farmers had the land holdings between 0.5 to 5.0 ha. However, small farmers with land holdings up 0.5 ha were also not uncommon (Table 12).

TABLE 12

Land use pattern in the selected villages

**PLACE TABLE 12 HERE**

The farmers plant up to three crops per year. Poplar and Eucalyptus plantings on farmlands average around 40 ha in last five years, 75% of which was Poplar, although it is now in decline because of falling Poplar prices in the market (Table 13).

TABLE 13

Area planted in last five years

**PLACE TABLE 13 HERE**

The farmers at present appear to be more inclined to plant horticulture crops such as Mango and Litchi, which are long rotation and provide handsome returns on regular basis, i.e., Mango, every two years and Litchi, every year (Table 14).

TABLE 14

Mitigation potential in terms of area.

**PLACE TABLE 14 HERE**

Another factor responsible for farmers switching over to horticulture crops is the declaration of the study site area as an Export Promotion Zone recently, where processing plants for fruit crops are expected to be developed. The survey of neighboring markets in Ramnagar, Kashipur, Haldwani and Yamunanagar revealed high potential demand for the produce of the five target species in Table 15.

TABLE 15

PROCOTAP key input data.

**PLACE TABLE 15 HERE**

The PROCOMAP benefit/cost analysis assumed that suitable land would be available to fully implement the options considered. The costs taken into account are the opportunity cost of land, preparation of land, cost of purchasing and planting of seedlings along with silvicultural and recurring costs of maintenance and monitoring. The benefits were calculated on the basis of local market rates for different products such as saw logs, chip logs, pulp logs, poles, veneer, fuel-wood and of fruits which were expected as output under mitigation scenario (Table 16).

TABLE 16

Establishment cost and carbon stored under tree plantations (2005 – 2035).

**PLACE TABLE 16 HERE**

If all plantations are fully established and maintained, by 2035 the total carbon stored over an area of 2,667 ha to be dedicated to plantation under mitigation scenario would be 195,853 tons, with an average annual incremental rate 2.45 tons of carbon per ha (Table 17). Total carbon expected to be stored under mitigation scenario in the absence of wood products would be 138,734 tons.

TABLE 17

Annual incremental carbon and total carbon sequestered under tree plantations for assessment period (2005-2030) with wood products

**PLACE TABLE 17 HERE**

Aggregate annual C pool increment under mitigation scenario with and without wood products is shown in Fig. 6, and mitigation scenario versus baseline results are shown in Fig. 7, where the model was run for 100 years. Similarly aggregate annual C stock increments in different C pools under the mitigation scenario are presented in Fig 8.

**PLACE FIGURE 6 HERE**

*Figure 6. Aggregate annual C pool increment for project activities in Bazpur.*

**PLACE FIGURE 7 HERE** *Figure 7. Aggregate carbon pools under baseline and project scenarios.*

**PLACE FIGURE 8 HERE**

*Figure 8.* Aggregate annual C stock increment in different C Pools for project activities in Bazpur.

Table 18 shows the cost effectiveness indicators at three different discount rates for the mitigation option. The net present value (NPV) represents the net direct benefit / loss from implementing the project. The net present value at 6% discount rate was calculated to be Rs. 196, 1,580 and 7,891 on per ton of carbon sequestered basis for Poplar, Eucalyptus and Teak respectively. However, when wood products were not included, the net present value calculated was Rs. 330, 1,953 and 8,810 for Poplar, Eucalyptus and Teak respectively.

TABLE 18

Cost effectiveness indicators without and with wood products (2005 – 2035)

**PLACE TABLE 18 HERE**

NPV obtained for all the interventions is positive except for Poplar plantations at a discount rate of 10%, so all plantations considered could be economically viable if the investment capital is obtained at the discount rates up to 8.0 percent. However, at higher discount rates, investment on poplar planting would cease to be economically viable, even though its carbon returns are the highest. This is also supported by the internal rate of returns calculated for different interventions, i.e., 9.5%, 20.7%, 19.7%, 14.76% and 37% for Poplar, Eucalyptus, Teak, Mango and Litchi respectively. Litchi recorded the highest IRR because of very high demand for litchi fruits. The Eucalyptus and Teak wood products are also high in demand as is reflected by their higher IRRs.

The farmers approach local banking institutions for credit, the rate for which varies from 10-11% with conditions that repayment begins after three years and is completed by the 5th year (for horticulture). The discount rates used of 6, 8 and 10 % appear reasonable. A hurdle rate of 20% appears appropriate for short-term farm forestry activities, but for long-term interventions such as Mango or Litchi it may be as low as 10-12%.

A carbon price of \$11.35 will be required to make the interventions acceptable to the farmers for Poplar growing. The cultivation of Eucalyptus, Teak, mango and Litchi can be taken up exclusive of C benefits. However, teak cultivation on farm lands will require relaxation in timber transport rules.

### 3.5 Leakage Analysis

The study has revealed that 52.1 % of fuelwood demand is met from the nearby forest areas and the rest from agricultural land. The project activity is envisaged only on agriculture land on an area of 2,667 ha, which is 11.5 % of the cultivated land. The quantity of fuelwood and small timber poles previously provide from this project area is now expected to be removed from nearby forest areas, a form of leakage calculated at 1,398 tons per annum (Table 19), and equivalent to 36,355 tons during the period of analysis,. This totals about 20% of the gross mitigation potential calculated for the project. The impact of leakage was not considered in the financial analysis.

TABLE 19

Estimation of leakage

**PLACE TABLE 19 HERE**

### 4. Discussion

The two case studies presented above depict the mitigation potential using various interventions ranging from short rotation to long rotation with and without benefits from wood products. These are summarized in Table 20 below:

TABLE 20

Overview of mitigation options and project technical issues

**PLACE TABLE 20 HERE**

The assessment of an afforestation option carried out in the present study has shown that high carbon mitigation potential exists on farmlands under short rotation cycles and on Van Panchayat lands under long rotation timber producing cycles. Each of the interventions, however, is beset with incentives and drawbacks. The short rotation timber species such as Eucalyptus, Poplar have high IRR but also high carbon benefit reversibility potential due to fluctuations in market prices of commodities produced. Long rotation timber species such as pine, mixed plantations have low IRR and hence without carbon benefits provide little incentive for investors. The carbon reversibility risk is lower in pine, mixed species plantation and mango (Table 20). The long rotation species however have to withstand the biotic pressure due to grazing and fodder collection. Social fencing has been successful in this region. The horticulture options are fruit species of mango, litchi



and kinoo on farmlands. The barriers associated with these are fluctuations in market prices and institutionalization of wholesale marketing.

#### 4.1 Barriers to implementation of A and R projects

The afforestation program conceived here faces barriers to implementation, including:

- Inadequate extension activities by the government on creating public awareness of the economic and environmental benefits of tree planning activities,
- Unorganized markets,
- Use of inappropriate planting material, planting and management techniques,
- Absence of agro-foresters co-operatives,
- Inadequate financial support and access to credit,
- Weak institutional capabilities of forest department as regards technical manpower to effectively demonstrate raising, maintenance and disposal of quality plantations,
- Exploitation of farmers by middlemen and industry, and
- The cultivation of valuable timber tree crops such as teak require relaxation of rules controlling the tree felling and timber transport. Many farmers are willing to take up teak growing on their farmland but for want of permission to fell and transport, the teak growing activities have not become popular.

These barriers would require appropriate action by stakeholders, particularly the government and the farmers, to assist farmers with technical information, quality planting material, access to credit, formation of farmers co-operatives, and favorable market environments.

#### 4.2 Considerations for Project Development – Lessons Learnt

##### **Site Selection**

The micro-selection of lands for the project site is an important aspect. A given region may have low C density and low land use change. If the site chosen or lands adjacent have high C and land use change rates, then the project location is probably unsuitable. For example, *Van Panchayat* lands were largely abandoned 10 yrs ago, are minimally regenerating, with little active management and so such areas present a good baseline for options. On the contrary, farm forestry lands in Bazpur have high rate of land use intensity, active cropping and relatively active adoption of new

cash crops and rich soils. In such areas, baseline and opportunity costs tend to be quite high. *Additionality* is also an issue if the target species or system is being adopted at a high rate in farm lands. *Additionality* could be based on barrier analysis for example, identification of areas where the target species is not occurring, and barriers to its adoption.

The best site is one with a combination of a low C density landscape, low land use change baseline, low adoption of other new practices, low potential for leakage (as few commodity crops or goods are grown and traded on markets), low potential for reversibility, low encroachments rates, stable land tenure, etc.

### **Bundling**

In both case studies, the land holdings are very small in size which means that bundling of small parcels is critical issue to achieve economies of scale of options. Research is needed to figure out how to bundle, measure and monitor small dispersed parcels into projects.

## **5. Conclusion**

Whilst GHG mitigation programs and agencies interested in forestry mitigation projects have a major objective of sustainable development, the afforestation of community lands in Uttarakhand State offer a significant opportunity for combining carbon trade, local institutions, peoples participation, environmental improvement and livelihood issues. The challenges and merits highlighted will need to be overcome through an integrated approach. These mitigation projects are required to play a multifunctional role that includes biodiversity conservation, improvement of ecosystem and yields of goods and services to the community generally. The project is financially viable though not highly lucrative but the carbon mitigation potential in this 'restoration of degraded lands' type of project is immense provided challenges in the initial phase are adequately overcome.

Prior to full-fledged implementation of such projects, methodological concerns such as sampling intensities, monitoring methodologies and sharing of benefits within communities will need to be refined to reduce transaction costs. While for small scale A and R activities project-level baselines may be workable, the development of baselines on a regional scale where large expanses of similar lands are available for A and R activities would most likely reduce transaction costs and

increase the ability of project developers and local communities to identify cost-effective mitigation options for their conditions.

### **Acknowledgement**

This work was supported by the U.S. Environmental Protection Agency, Office of Atmospheric Programs through the U.S. Department of Energy under Contract No. DE-AC02-05CH11231. We also thank DG (ICFRE) Mr. R.P.S Katwal and Principal Chief Conservator of Forests, Forest Department, Uttaranchal for facilitating support for undertaking this study. The authors are grateful to Research Coordinator, Forest Research Institute, Dr. Anil Kumar Hooda, for help with data analysis. Authors are also grateful to Dr. N.H. Ravindranath, Indu Murthi, P. Sudha and Giresch Mohan Joshi for review, discussions and comments and N.C. Kahera and Yogendra Vrihaspati for general logistical assistance in preparation of this report. Disclaimer: The views and opinions of the authors herein do not necessarily state or reflect those of the United States Government or the Environmental Protection Agency.

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## Captions

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Overview of the study sites and carbon mitigation options.

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Area by land use category in the Betalghat project site.

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Carbon ( $\text{t ha}^{-1}$ ) in aboveground, belowground and soil carbon pools under different land uses in project area.

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Overview of mitigation options and project technical issues

*Figure 1.* Distribution of *Van Panchayat* institutions managing *Van Panchayat* lands in Uttarakhand State (Adapted from Kumar A., 2000)

*Figure 2.* Flow diagram of approach to mitigation analysis using PROCOMAP model.

*Figure 3.* Schematic map of land use and mitigation options in hilly areas of Betalghat watershed.

*Figure 4.* Aggregate annual C stock increment in different C pools for all project activities in Betalghat.

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*Figure 7.* Aggregate carbon pools under baseline and project scenarios.

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**Table 1.** Overview of the study sites and carbon mitigation options.

Potential mitigation option	Case Study	Area (ha)
1. Community Forestry on degraded <i>Van Panchayat</i> lands (community managed areas with support from forest department)	Betalghat (part watershed) Nainital district	1,589
2. Farm forestry on private croplands	Bazpur (Udham Singh Nagar district)	2,667

**Table 2.** Area by land use category in the Betalghat project site.

<b>Total Area in Project site<sup>1</sup></b>				
<b>Civil/Soyam lands</b> (These are under the ownership of Revenue Department)	<b>Van Panchayat lands</b> (These lands are under management of local <i>Van Panchayats</i> ; Ownership of lands is with Revenue department)	<b>Agriculture/C roplands</b> (Private lands under the ownership of farmers/ individuals)	<b>Reserve Forest</b> (Areas under government ownership, managed by Forest Department and notified under the Indian Forest Act)	<b>Total (ha)</b>
1,125	2,075	1,345	336	<b>4,881</b>
<b>Surplus Area available for afforestation by land use<sup>2</sup></b>				
248	846	495	170	<b>1,759</b>

Source: <sup>1</sup>*Panchayati vanon ke sanhad prabhand yojana, janpad Nainital; Varsh 2003-08; Nainital van Prabhag, Nainital.*

<sup>2</sup> *Actual survey data*



**Table 3.** Carbon (t ha<sup>-1</sup>) in aboveground, belowground and soil carbon pools under different land uses in project area.

Land Use Category	Carbon (t ha <sup>-1</sup> )		
	Civil/Soyam	Van Panchayat	Agriculture
Soil carbon	36.5 (19.1 to 52.8)*	56.3 (46.3 to 68.7)	59.7 (42.4 to 86.7)
Aboveground carbon	0.9	5.1	3.6
Belowground carbon	0.2	1.3	0.9
Woody Litter	0.1	0.1	0.1
<b>Total Carbon</b>	<b>37.7</b>	<b>62.8</b>	<b>64.3</b>

*Source: Based on actual measurements.*

**Table 4.** PROCOMAP Key Input Data.

<b>Data Inputs to PROCOMAP Model</b>					
	<b>Khair (Long rotation with harvesting)</b>	<b>Pine (Long Rotation with harvesting and 1 thinning)</b>	<b>Mixed Species plantation (regeneration with harvest for fuelwood and grass)</b>	<b>Mango (regeneration, no harvest)</b>	<b>Kinoo (Short rotation with harvest for fuelwood)</b>
Area for plantation (ha)	248	543	300	300	198
Rotation (yrs)	30	80	80	60	15
Phasing (yrs)	4	10	5	6	6
MAI (tB/ha/yr)	2.29	12	8.6	2.8	0.2
Woody Litter (t/ha/yr)	0.3	0.3	0.3	0.5	0.3
Decomposition Period (yrs)	2.3	5.3	5.3	4	3.1
Opportunity Cost of land (Rs)	1,250	2,000	2,000	8,000	6,000
Main products	Chip logs tannin	Polewood, grass resin Sawlogs at 80 yrs	Fuelwood, Grass, resin	Fruits	Fruits

**Table 5.** Carbon stock change under baseline and mitigation scenario and the carbon increment per ha for various interventions for the period 2005-2035 (tC/ha).

Interventions- (all block plantations)	2005	2010	2015	2020	2025	2030	2035
<b>Khair</b>							
Baseline	47.3	47.3	47.3	47.3	47.3	47.3	47.3
Mitigation	48.5	60.0	71.4	82.3	88.7	94.6	70.5
<b>Incremental</b>	1.2	12.8	24.1	35.0	41.4	47.3	23.2
<b>Chir Pine</b>							
Baseline	58.6	58.6	58.6	58.6	58.6	58.6	58.6
Mitigation	62.7	104.1	145	185.9	227.4	268.4	309.4
<b>Incremental</b>	4.1	45.5	86.5	127.5	168.8	209.8	250.8
<b>Mixed Plantation</b>							
Baseline	58.6	58.6	58.6	58.6	58.6	58.6	58.6
Mitigation	61.7	93.3	124.6	156.0	187.5	218.9	250.3
<b>Incremental</b>	3.2	34.7	66.1	97.4	129.0	160.3	197.9
<b>Mango</b>							
Baseline	59.7	59.7	59.7	59.7	59.7	59.7	59.7
Mitigation	60.8	70.9	81.0	90.9	98.8	106.9	115.0
<b>Incremental</b>	1.1	11.2	21.3	31.3	39.1	47.2	55.3
<b>Kinoo</b>							
Baseline	36.9	36.9	36.9	36.9	36.9	36.9	36.9
Mitigation	37.6	41.2	41.6	41.0	41.4	41.6	41.1
<b>Incremental</b>	0.7	4.3	4.6	4.1	4.4	4.7	4.1

**Table 6.** Average annual incremental carbon and total carbon sequestered under tree plantation (without wood products) for assessment period (2005 – 2035).

<b>Intervention</b>	<b>Land area (ha)</b>	<b>Average Annual incremental C (tC)</b>	<b>Average Annual incremental C per ha (tC ha<sup>-1</sup>)</b>	<b>Total C stored</b>
Khair	248	372.2	1.5	11,165
Pine	543	3,868.1	7.1	116,044
Mixed	300	1,790.4	5.9	53,713
Mango	300	512.7	1.7	15,381
Kinoo	198	31.3	0.2	939
<b>Total</b>	<b>1,589</b>	<b>1,818.6*</b>	<b>4.1*</b>	<b>197,242</b>

\* Weighted average figures

**Table 7.** Establishment cost and carbon stored under tree plantations.

<b>Intervention</b>	<b>Land area (ha)</b>	<b>Initial cost (Rs.ha<sup>-1</sup>)</b>	<b>Initial Cost (\$ ha<sup>-1</sup>)**</b>	<b>Unit cost (without wood products) (Rs t<sup>-1C</sup>)</b>	<b>Unit cost (\$ t<sup>-1C</sup>)**</b>	<b>Mitigation potential (ha<sup>-1</sup>)</b>
Khair	248	11,525	256	3,192	70.9	45
Chir Pine	543	13,049	290	2,920	64.9	213
Mixed Plant.	300	14,159	315	210	4.7	163
Mango	300	10,150	226	817	18.2	51
Kinoo	198	18,938	421	21,862	485.8	5
<b>Total</b>	<b>1,589</b>	<b>11,763*</b>	<b>261</b>	<b>3,987.69</b>	<b>88.6</b>	<b>112.8*</b>

\* Weighted average value

\*\*Exchange rate (1\$=Rs.45)

**Table 8.** Cost effectiveness indicators for mitigation options for the period 2005-2035.

Intervention	Land Area (ha)	Discount rates (%)	Net Present Value	
			Rs /tC	Rs/ha
<b>Khair</b>	248			
(IRR 8.5%)		6	868	37,335
		8	124	5,332
		10	-263	-11,324
<b>Pine</b>	543			
(IRR 2.2 %)		6	-29	-6,114
(IRR 6.6%)*		8	-41	-8,768
(IRR 8.3%)**		10	-47	-10,023
<b>Mixed</b>	300			
(IRR -2%)		8	-142	-23,220
(IRR 1.6%)		10	-135	-2,216
(IRR 3.9%)		12	-127	-20,767
<b>Mango</b>	300			
(IRR 16%)		6	4,405	225,839
		8	2,490	127,674
		10	1,334	68,390
<b>Kinoo</b>	198			
(IRR 20.5%)		6	36,375	172,606
		8	24,512	116,316
		10	16,455	78,082

\* IRR for the period of 2005 – 2054

\*\* IRR for the period of 2005 – 2084

Exchange rate (1\$=Rs.45)

**Table 9. Internal** rate of return for project interventions with carbon revenue.

Intervention	Carbon Scenario (without wood products)			Carbon Price at 10% hurdle rate (Rs.)
	C1*	C2*	C3*	
<b>Khair</b>	9%	10.7%	13.1%	711
<b>Pine</b>	8.1%	25.8%	39.3%	288
<b>Mixed Plantation</b>	3.7%	17%	24.6%	577

\*C1 – Carbon price at \$5 per tonne (Rs. 230). No net increase in carbon price with time.

C2 – Increase in carbon price at the rate of 2% per annum subject to maximum of \$100 (Rs. 4,600)

C3 – Increase in carbon price at the rate of 5% per annum subject to maximum of \$100 (Rs. 4,600)

Exchange rate (1\$=Rs.45)

**Table 10.** Annual demand and supply of fodder (mt).

<b>Village</b>	<b>Cow unit</b>	<b>Fodder Requirement</b>	<b>Fodder availability</b>	<b>Gap</b>
Bajeri	691	1,623.9	373.7	-1,250.1
Ghodia Halsan	414	972.9	663.2	-309.7
Haroli	124	291.4	393.3	101.9
Majhera	411	965.9	213	-752.9
Simalkha	305	716.8	169.8	-547.0
<b>Projection for Total Project Area with 48 villages</b>	<b>10,747</b>	<b>25,258.2</b>	<b>7,939.8</b>	<b>-17,318.3</b>

Source: Panchayati vanon ke sanhad prabhand yojana, janpad Nainital; Varsh 2003-08; Nainital van Prabhag, Nainital.



**Table 11.** Annual demand and supply of fuelwood (tm).

<b>Village</b>	<b>Families</b>	<b>Fuelwood Requirement (tonnes metre)</b>	<b>Fuelwood collection Total (tonnes metre)</b>	<b>Fuelwood collection from community lands (tonnes metre)</b>	<b>Gap (tonnes metre)</b>
Bajeri	109	397.9	204.3	10.2 (5%)	-193.7
Ghodia Halson	150	817.4	652.5	93.8 (14.37%)	-164.9
Haroli	40	189.8	107	78.4 (7.33%)	-82.8
Majhera	173	521.8	324.2	0 (0%)	-197.6
Simalkha	94	482.4	431.5	22.4 (5.18%)	-50.9
<b>Extrapolation to Total Area</b>	<b>2825</b>	<b>20,544.8</b>	<b>18,653.5 (100%)</b>	<b>1,305.7 (at 7%)</b>	<b>-1,891.8</b>

Source: Based on survey data

**Table 12.** Land use pattern in the selected villages

Sl. No.	Name of village	Land use pattern (Ha)				Land holding pattern		
		Forest	Agricultural land	Area not available for agriculture	Total	Small	Medium	Large
1	Majra	153.4	46.5	4.5	204.4	26 (< 2 ha)	11(2 - 8 ha)	Nil (> 8 ha)
2	Chanakpur	248	226.6	15	489.6	94 (< 0.4 ha)	40 (0.4 - 2 ha)	25 (>2 ha)
3	Bhainsia	Nil	120	6	126	10 (< 2 ha)	25 (2 - 8 acre)	Nil (>8 ha)
4	Vikrampur	Nil	585.7	15	600.7	148 (< 0.4 ha)	7 (0.4 - 2 ha)	35 (>2 ha)
5	Intwa	Nil	155	20	175	308 (< 0.4 ha)	135 (0.4 - 2 ha)	12 (>2 ha)

**Table 13.** Area planted in last five years

Sl. No.	Name of villages	* Area brought under tree plantation on agriculture land in last 5 yrs (ha)	Percent area under different species in AF/ FF	
			Poplar	Eucalyptus
1	Majra	3.6	65	35
2	Chanakpur	10	85	15
3	Bhainsia	42	69	31
4	Vikrampur	135**	75	5
5	Intwa	5.6	85	15

*\*Area equivalent of block plantation @500 trees/ha.*

*\*\* Remaining area under Litchi and Mango cultivation.*

**Table 14.** Mitigation potential in terms of area.

Sl. No	Name of villages	Area		Area planted in last 5 yrs	Potential area and choice of species	
		Forest	Agriculture		Area (ha)	Choice of species (area in ha)
1	Majra	153.39	46.5	3.6	10 (Forest) 30 (Agri land)	Arjun, Jamun, Bakain, Paper Mulberry (10) Eucalyptus, Poplar, Teak (10 each)
2	Chanakpur	248	226.6	10.0	150 (Agri land)	Poplar (50) Eucalyptus (25) Teak (50) Sissoo, Mango, Litchi (25)
3	Bhainsia	Nil	120	42.0	80 (Agri land)	Eucalyptus (20) Poplar (50) Mango (10)
4	Vikrampur	Nil	585.7	135.0	350 (Agri land)	Poplar (250) Litchi (90)
5	Intwa	Nil	155	5.6	15 (Agri land)	Mango (10)

*Surplus area available for mitigation = to 4375 ha approx.*

**Table 15.** PROCOMAP key input data.

<b>Input services</b>	<b>Poplar</b>	<b>Eucalyptus</b>	<b>Teak</b>	<b>Mango</b>	<b>Litchi</b>
Land area dedicated (ha)	1,190	590	177	355	355
Rotation (yrs)	6	10	20	60	60
M.A.I (tB/ha/yr)	25.2	11.3	10.8	2.8	2.8
Rate of carbon uptake in soil (tC/ha/yr)	1.2	1.1	2.2	0.2	0.20
Woody litter (tB/ha/yr)	0.4	0.3	0.3	0.4	0.5
Decomposition period (yrs)	2.9	3.6	3.1	4	4
Opportunity cost of land Rs/ha (dollars/ha**)	20,000 (\$ 444)	8,000 (\$ 178)	10,000 (\$222)	8,000 (\$178)	8,000 (\$ 178)
<b>Product life:</b> Saw logs 70 yrs; Chip logs 30 yrs; Pulp logs 3 yrs; Poles 12 yrs; Veneer 30yrs					
<b>Analysis period:</b> 2005 – 2035					
**Exchange rate (1\$=Rs.45)					

**Table 16.** Establishment cost and carbon stored under tree plantations (2005 – 2035).

Intervention	Land area (ha)	Initial cost (Rs.ha <sup>-1</sup> )	Initial cost (\$ ha <sup>-1</sup> )**	Unit cost				Mitigation potential tC (ha <sup>-1</sup> )	Carbon flow (tC)
				With wood products		Without wood products			
				(Rs t <sup>-1C</sup> )	(\$ t <sup>-1C</sup> )	(Rs t <sup>-1C</sup> )	(\$ t <sup>-1C</sup> )		
Poplar	1,190	12,950	288	5,935.1	131.9	1,942.3	43.2	100 (58)***	119,000 (69,020)
Eucalyptus	590	4,500	100	3,422.1	76.1	1,144.7	25.5	53 (43)	31,270 (25,370)
Teak	177	17,249	383	2,583.4	57.4	2,042.1	45.9	69 (62)	12,213 (10,974)
Mango	355	10,150	226			890.4	19.8	47	16,685
Litchi	355	10,150	226			976.2	21.7	47	16,685
Total	2,667	10,621*	236	4,874.3 ****	108.4	1,503.84	33.42	73.4 (53.8)****	195,853 (138,734)

\* Weighted average value

\*\*Exchange rate (1\$=Rs.45)

\*\*\* Figures in parenthesis refer to without wood products

\*\*\*\*Mango and litchi not included

**Table 17.** Annual incremental carbon and total carbon sequestered under tree plantations for assessment period (2005-2030) with wood products

<b>Intervention</b>	<b>Land area (ha)</b>	<b>Annual incremental C (tC)</b>	<b>Annual incremental C per ha (tCha<sup>-1</sup>)</b>	<b>Total C stored</b>
Poplar	1,190	3,962.7	3.33	119,000
Eucalyptus	590	10,44.3	1.77	31,270
Teak	177	407.1	2.3	12,213
Mango	355	556.2	1.57	16,685
Litchi	355	556.2	1.57	16,685
<b>Total</b>	<b>2,667</b>	<b>2,174.24*</b>	<b>2.45*</b>	<b>195,853</b>

\* Weighted average value

**Table 18.** Cost effectiveness indicators without and with wood products (2005 – 2035)

Interventions	Land area (ha)	Discount rates (%)	Net present value: without wood products, (with wood products)	
			Rs t <sup>-1</sup> C	Rs ha <sup>-1</sup>
Poplar	1,190	6	196 (330)	18,250
%		8	63 (106)	5,832
(IRR 9.5%)		10	-17 (-29)	-1,579
Eucalyptus	590	6	1,580 (1,953)	83,428
%		8	1,069 (1,321)	56,452
(IRR 26.4%)		10	728 (899)	38,415
Teak	177	6	7,891 (8,810)	542,183
%		8	4,801 (5,360)	329,860
(IRR 20.7%)		10	2,894 (3,231)	198,826
Mango	355	8	1,923	90,615
%		10	975	45,927
(IRR 14.76%)		12	414	19,509
Litchi	355	8	14,009	660,171
%		10	9,279	437,282
(IRR 37%)		12	6,226	293,381

Exchange rate (1\$=Rs.45)



**Table 19.** Estimation of leakage

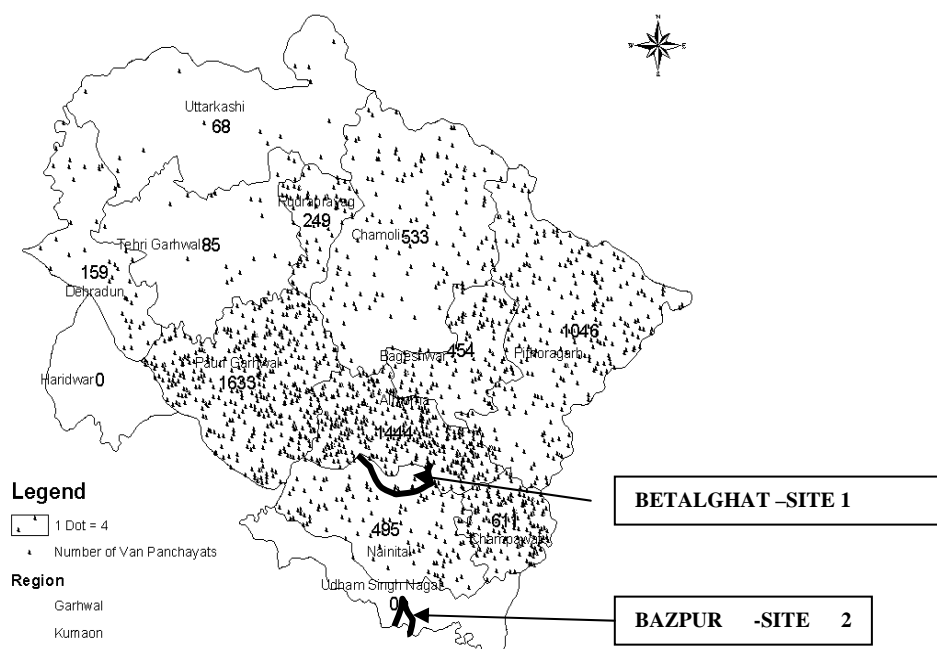
S. No	Name of village	Fuelwood collection (t/Yr)			Small timber collection (No. of poles)			Fodder collection (t/yr)		
		Forest	Agri. land	Total	Forest	Agri. land	Total	Forest	Agri. Land	Total
1.	Majra	114 (84%)	23 (17%)	137	570 (100%)	Nil	570	789 (12%)	6,068 (88%)	6,856
2.	Chanakpur	426 (87%)	7 (14%)	493	1,113 (100%)	Nil	1,113	126 (42%)	176 (58%)	302
3.	Bhainsia	26 (29%)	65 (72%)	91	224 (32%)	476 (68%)	700	Nil	4,214 (100%)	4,214
4.	Vikrampur	Nil	266 (100%)	266	Nil	Nil	Nil	Nil	5,244	5,244
6.	Intwa	1274 (50%)	1274 (50%)	2,548	3003 (60%)	2002 (40%)	5005	2,370 (8%)	25,840 (92%)	28,210
<b>Project site</b>		128,834 (52% )	118,595 (48%)	247,429 (100)%	34,370 (66%)	17,346 (34%)	51,716 (100%)	22,989 (7%)	290,796 (93%)	313,786 (100%)

Table 20 Overview of mitigation options and project technical issues

Potential Mitigation Option, Location	Baseline Setting and Additionality	Leakage	Reversibility (non— permanence)	Financial Feasibility: IRR (%)
<b>Community Forestry Options: Betalghat Site, Nainital District</b>				
Pine and mixed species regeneration on Van Panchayat degraded lands: no timber harvesting, fuelwood or pole thinning, resin tapping and fodder collection is however, allowed.	<ul style="list-style-type: none"> <li>-Baseline is land use mosaic with mixed land tenure, degraded common lands, with low historic rate of reclamation, low carbon density.</li> <li>- Land use trends can be used to generate dynamic baseline.</li> <li>- Avoid species requiring irrigation.</li> <li>-Low opportunity costs, lands meant for enhancing conservation and plantation activities for local livelihoods</li> <li>-Intervention feasible with carbon revenue.</li> </ul>	<ul style="list-style-type: none"> <li>- Leakage estimate for fodder (2%) and fuelwood from community lands is 7% of mitigation potential. Total potential leakage is 10% [ from Section 1.4.3 in paper ]</li> <li>- Possible if fuelwood /fodder collection shifts elsewhere. Otherwise, low leakage likely.</li> <li>-Alternative energy sources can help to minimize leakage.</li> </ul>	<ul style="list-style-type: none"> <li>- Reversibility risk probably low, as community involved.</li> <li>Long Rotation species</li> <li>- Fodder production in project for village cows reduces pressure on regeneration.</li> <li>- Risks include:</li> <li>- encroachment within village</li> <li>- drought</li> <li>-market prices drive harvest and replanting in higher-IRR species</li> </ul>	<p>IRR 2.2 % without harvesting at 30 yrs age. Carbon price at 8% hurdle rate for Pine is Rs. 221 and Rs 288 at 10%. However, the project can realize an IRR of 8.3% at 80 yrs (rotation age) and beyond with harvest without C benefits.</p> <p>IRR with carbon revenue can increase upto 39% (Table 12)</p>
Mixed species regeneration on Van Panchayat degraded lands: no timber harvesting. Fuelwood, resin tapping and fodder collection is allowed.	<p>As above</p> <ul style="list-style-type: none"> <li>-low baseline,</li> <li>-interim returns from resin and fuelwood</li> </ul>	As above	<p>Mix of slow and medium increment growth rate species to increase carbon density. Low risk of reversibility as these are long rotation species of 80 yrs.</p> <ul style="list-style-type: none"> <li>-Broad leaved species provide interim returns in the form of fuelwood, polewood etc.</li> <li>-Alternative land use for such areas would be as grazing lands for which financial and technical inputs required are very high.</li> </ul>	<p>Negative at 30 yrs. Carbon price at 8% hurdle rate at is Rs. 466 and at 10% is Rs. 577 per t C.</p> <p>IRR is 3.9 % at 80 yrs without harvest and without carbon.</p> <p>-IRR with carbon revenue can increase upto 25% (Table 12)</p>
Khair long rotation plantations, with harvesting	As above	As above	<ul style="list-style-type: none"> <li>- Rotation 30 yrs</li> <li>Reversibility risk mainly due to natural causes mainly drought.</li> </ul>	<p>8.5% without wood products and carbon revenue.</p> <p>-IRR with carbon revenue can increase up to 13% (Table 12)</p>
Kinoo short rotation plantations, with no harvesting for timber (only fuelwood)	<ul style="list-style-type: none"> <li>-suitable for agricultural lands/farmland</li> <li>-low carbon mitigation potential</li> </ul>	As above	<ul style="list-style-type: none"> <li>-Rotation 8 yrs.</li> <li>Reversibility risk due to pests, disease and low market prices of fruit.</li> </ul>	<p>20.5% without carbon benefits and wood products</p>
Mango regeneration planting of fruit trees, no harvesting of timber	<ul style="list-style-type: none"> <li>-suitable for farmlands with adequate water availability</li> <li>-market prices are a barrier</li> </ul>	As above	<ul style="list-style-type: none"> <li>-rotation 60 years</li> <li>-Low reversibility risk</li> <li>-market demand always high.</li> </ul>	<p>16% without carbon benefits and wood products</p>
<b>Farm Forestry on Private Cropland Options: Bazpur Site, Udham Singh Nagar District</b>				
Poplar for plyboard market	<ul style="list-style-type: none"> <li>- Baseline is current land use and minor conversion into target species.</li> <li>- Potential to target planting to new areas</li> </ul>	<ul style="list-style-type: none"> <li>- :Leakage estimate for fuelwood and small wood is 20% of mitigation potential.[from Section 2.5 in paper]</li> </ul>	<ul style="list-style-type: none"> <li>- Reversibility potential is significant.</li> <li>Risks include:</li> <li>-market price decline could stimulate premature harvest and crop shifting</li> </ul>	<p>-IRR 9.5%.</p> <p>-For a hurdle rate of 20%, a carbon price of \$11.6 per ton of carbon will be required.</p>

	<p>not likely to be converted to poplar without the project. The barriers could be formation of farmers Co-operatives to deal with exploitation by the middle man and ensure correct price.</p> <p>- If commodity market prices increase, could change baseline planting rate over time.</p>	<p>- Market leakage possible, as produces commodity traded in near by markets. (i.e. Ramnagar, Kashipur and Yamuna nagar.)</p>	<p>- Project could monitor these risks.</p> <p>- Project could withhold some percentage of carbon as buffer against risks.</p>	
Eucalyptus for plywood, sawn wood, pulp and fuelwood.	As above	As above	<p>Reversibility potential mainly due to non-anthropogenic reasons that too restricted to Pests and Diseases. Fire and drought may not be a reality. Overall, non-permanence is not a serious issue due to price stability for last 7-8 years.</p>	IRR is 26.4% without C-benefits.
Teak for poles and Sawn wood	As above identified barrier is departmental permission required for felling and transportation of teak trees. This needs to be overcome with the project.	As above there is a high demand for a teak poles and sawn wood. Market leakage may not be a serious issue.	<p>Reversibility potential mainly due to non-anthropogenic reasons that too restricted to Pests and Diseases. Fire and drought may not be a reality. Overall, non-permanence is not a serious issue due to high demand.</p>	<p>-IRR is 20.7%</p> <p>-For a hurdle rate of 20%, a carbon price of \$1.79 per ton of carbon will be required.</p>
Mango trees for fruit	As above	As above	<p>As above, for fruit market. Non permanence is not a serious issue owing to long rotation (60 years) and no harvest included in this intervention. Moreover the demand for mangoes (fruit) always exists.</p>	IRR is 14.76 % without C-benefits.
Litchi trees for fruit	Since this intervention is associated with maximum IRR (36%), this becomes financially the most attractive option, which may not lead to an additionality.	As above	<p>As above, for fruit market. Non permanence is not a serious issue owing to long rotation (60 years) and no harvest included in this intervention. Moreover the demand for litchi (fruit) always exists and is in fact increasing.</p>	IRR is 37 % without C-benefits.

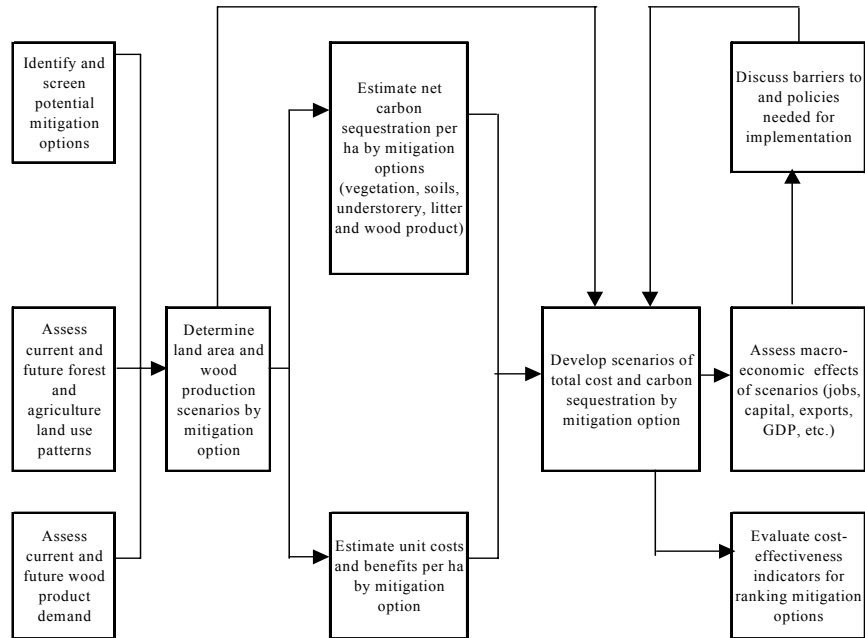
**Figure 1.** Distribution of *Van Panchayat* institutions managing *Van Panchayat* lands in Uttarakhand State (Adapted from Kumar A., 2000)



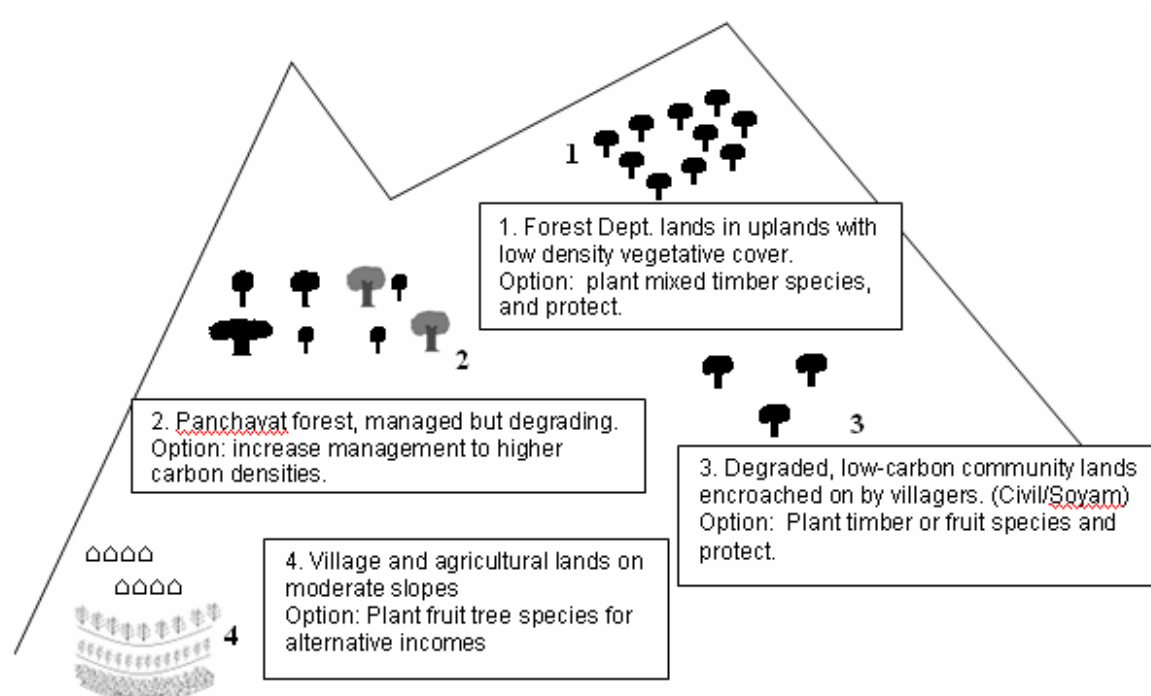
Note: *Van Panchayat* areas exist in Nainital district (Site 1) but none in Udham Singh Nagar district (Site 2) which is a farm forestry case.

In Nainital district the total area with *Van Panchayats* in Betalghat block is 4,044 ha This represents the total area potentially available for mitigation activities.

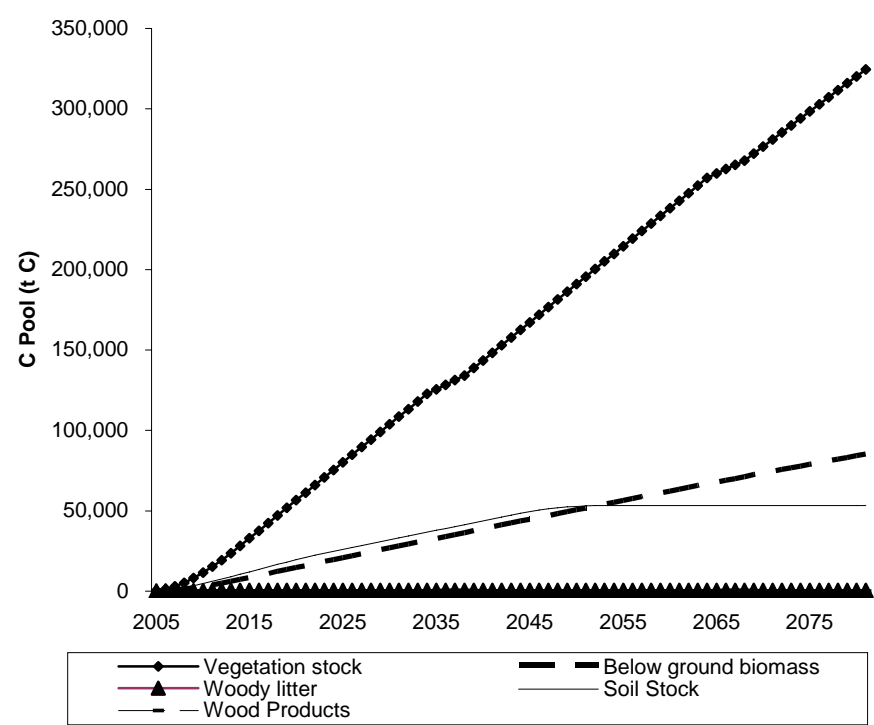
**Figure 2. Flow diagram of approach to mitigation analysis using PROCOMAP model.**



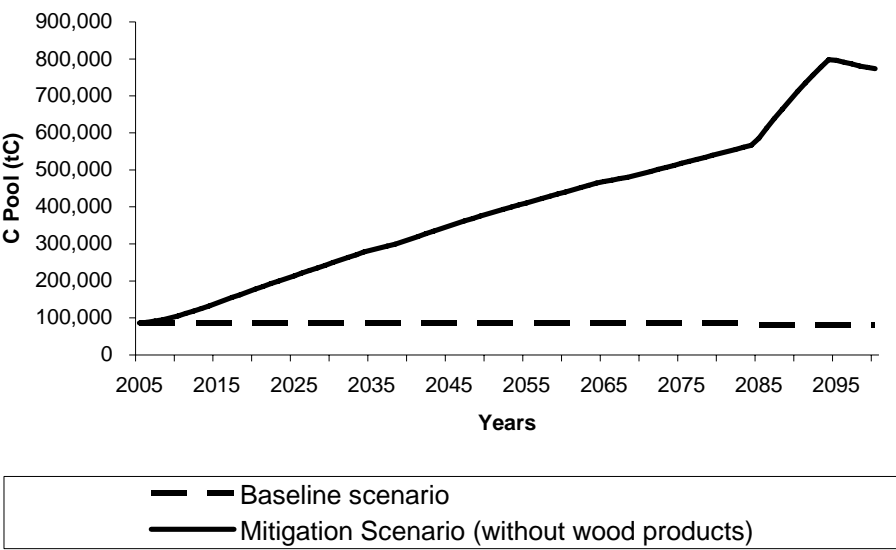
**Figure 3. Schematic map of land use and mitigation options in hilly areas of Betalghat watershed.**



**Figure 4.** Aggregate annual C stock increment in different C pools for all project activities in Betalghat.

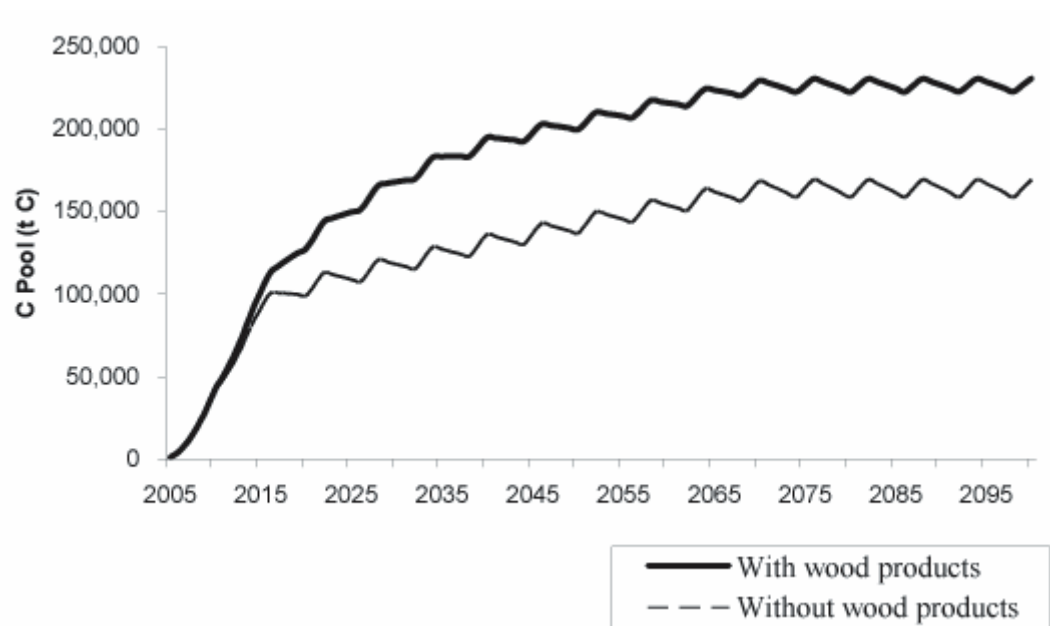


**Figure 5.** Aggregate carbon stocks under baseline and mitigation scenario for project activities in the Betalghat.

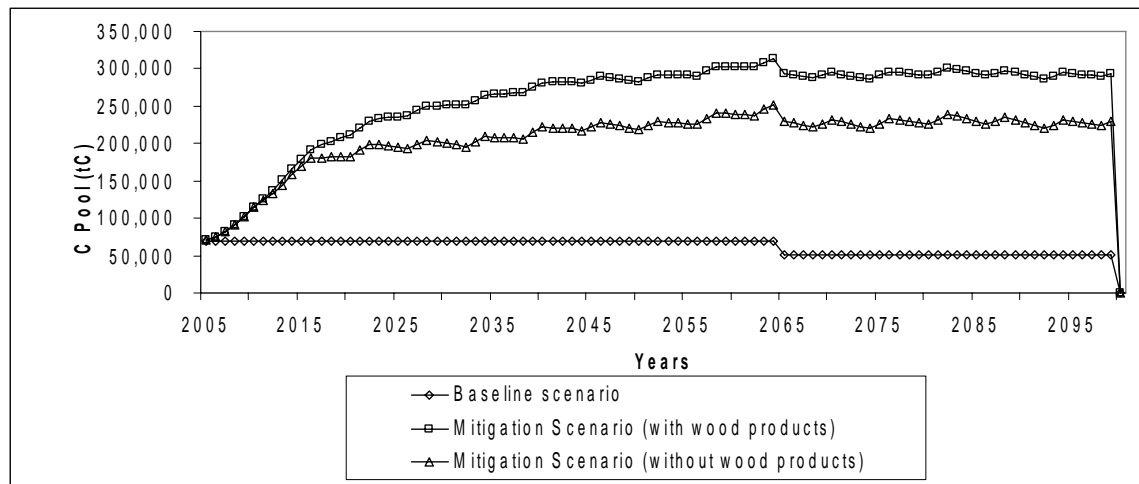




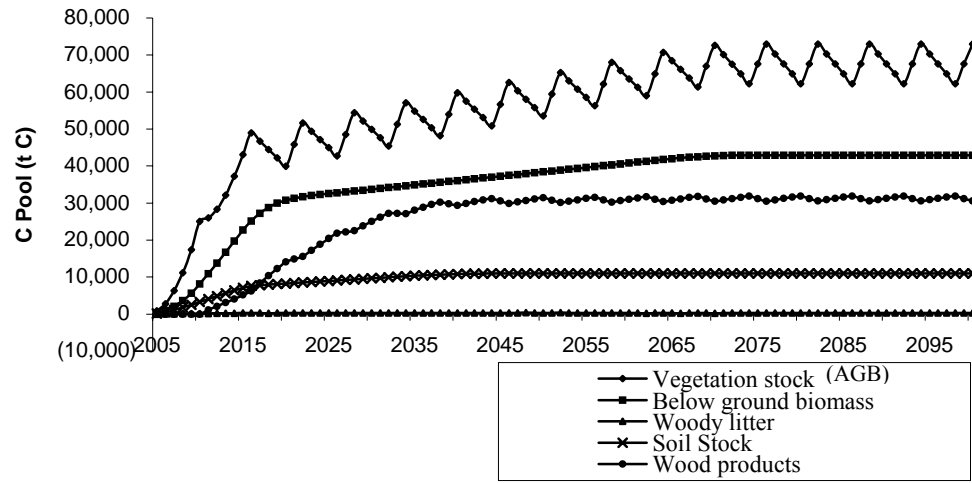
**Figure 6. Aggregate annual C pool increment for project activities in Bazpur.**



**Figure 7. Aggregate carbon pools under baseline and project scenarios.**



**Figure 8. Aggregate annual C stock increment in different C Pools for project activities in Bazpur.**



University Press, UK 2000.